Nutrient Management of Pacific Northwest Douglas-fir Plantations

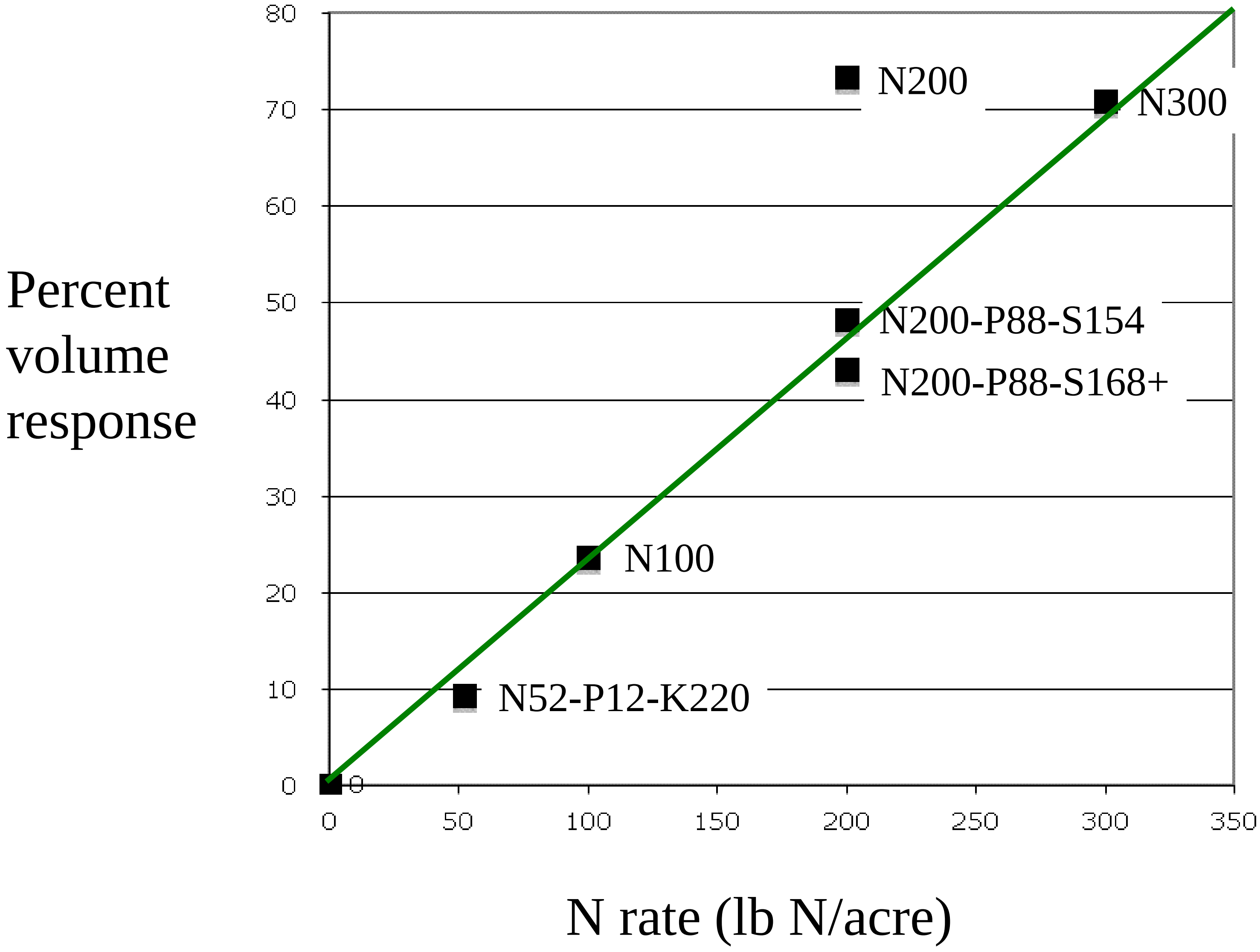
Rob Harrison, Eric Turnblom, Greg Ettl, Bob Gonyea, Bert Hasselberg, Kim Littke, Paul Footen, Scott Holub, Tom Terry, many others

Stand Management Cooperative
School of Environmental and Forest Sciences
College of the Enviornment
University of Washington
Seattle, WA 98125

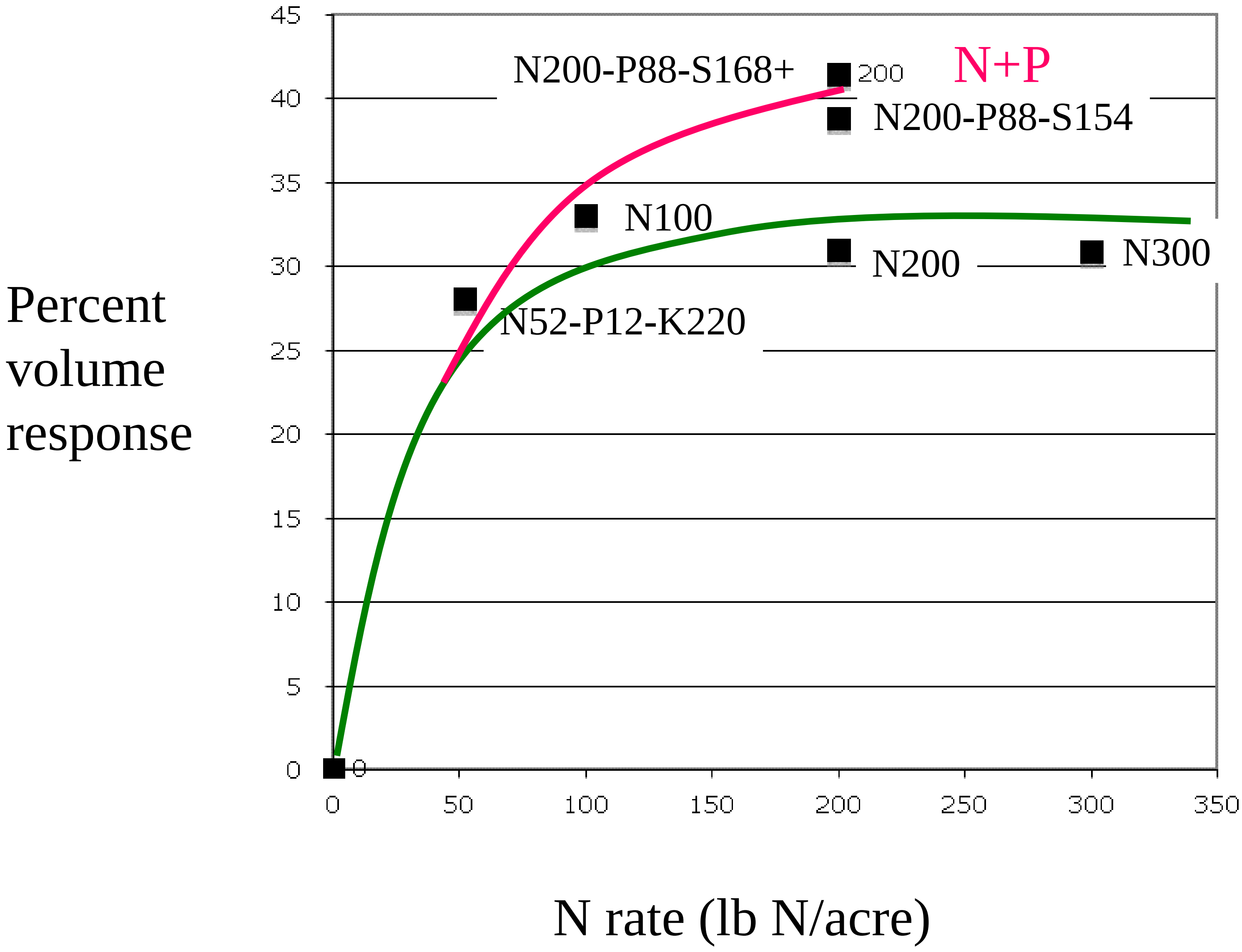
1) Early Work
2) Regional Studies
3) Current Research
4) Future Efforts

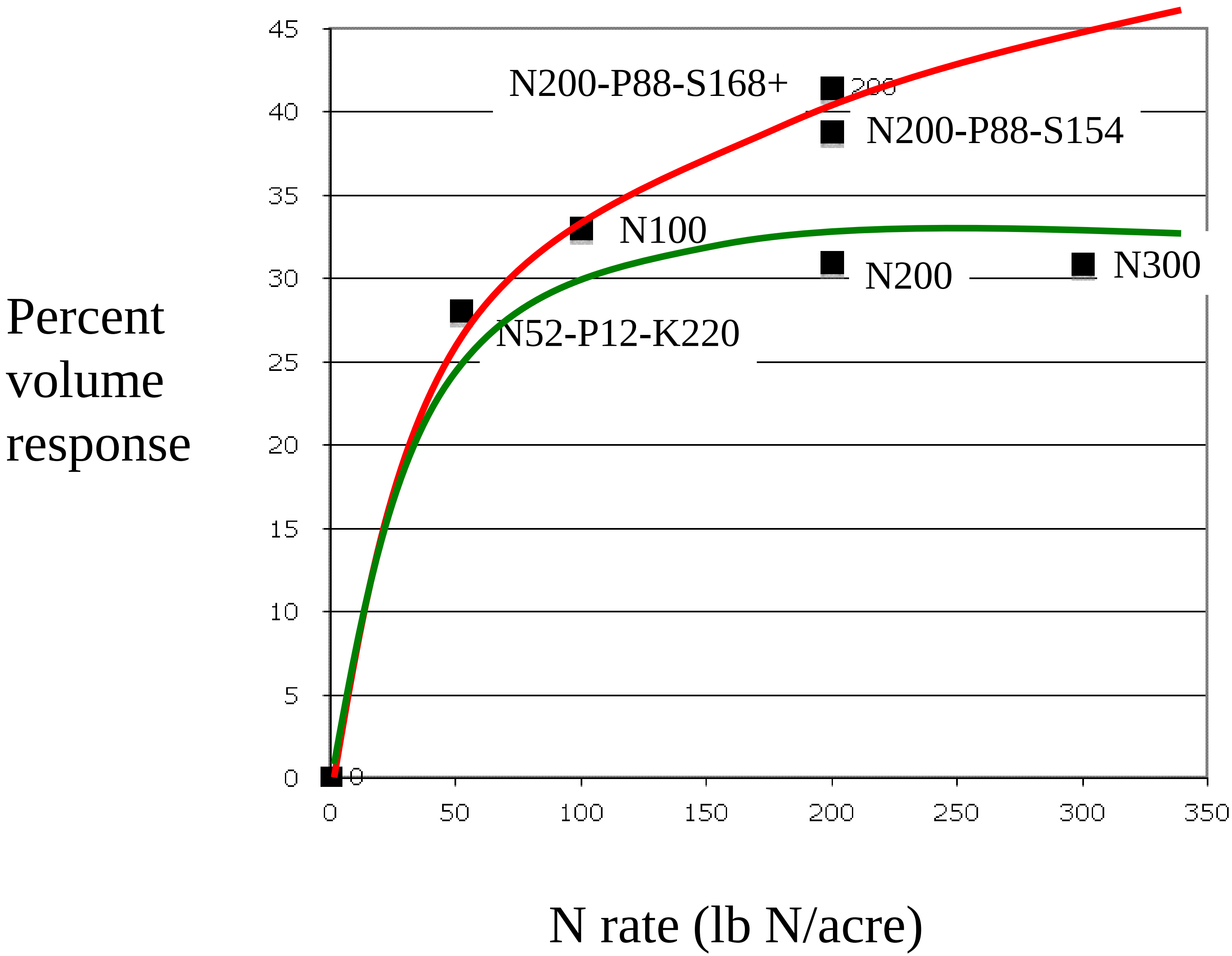
1) Early Work
Pre-RFNRP
1950's through 1960's

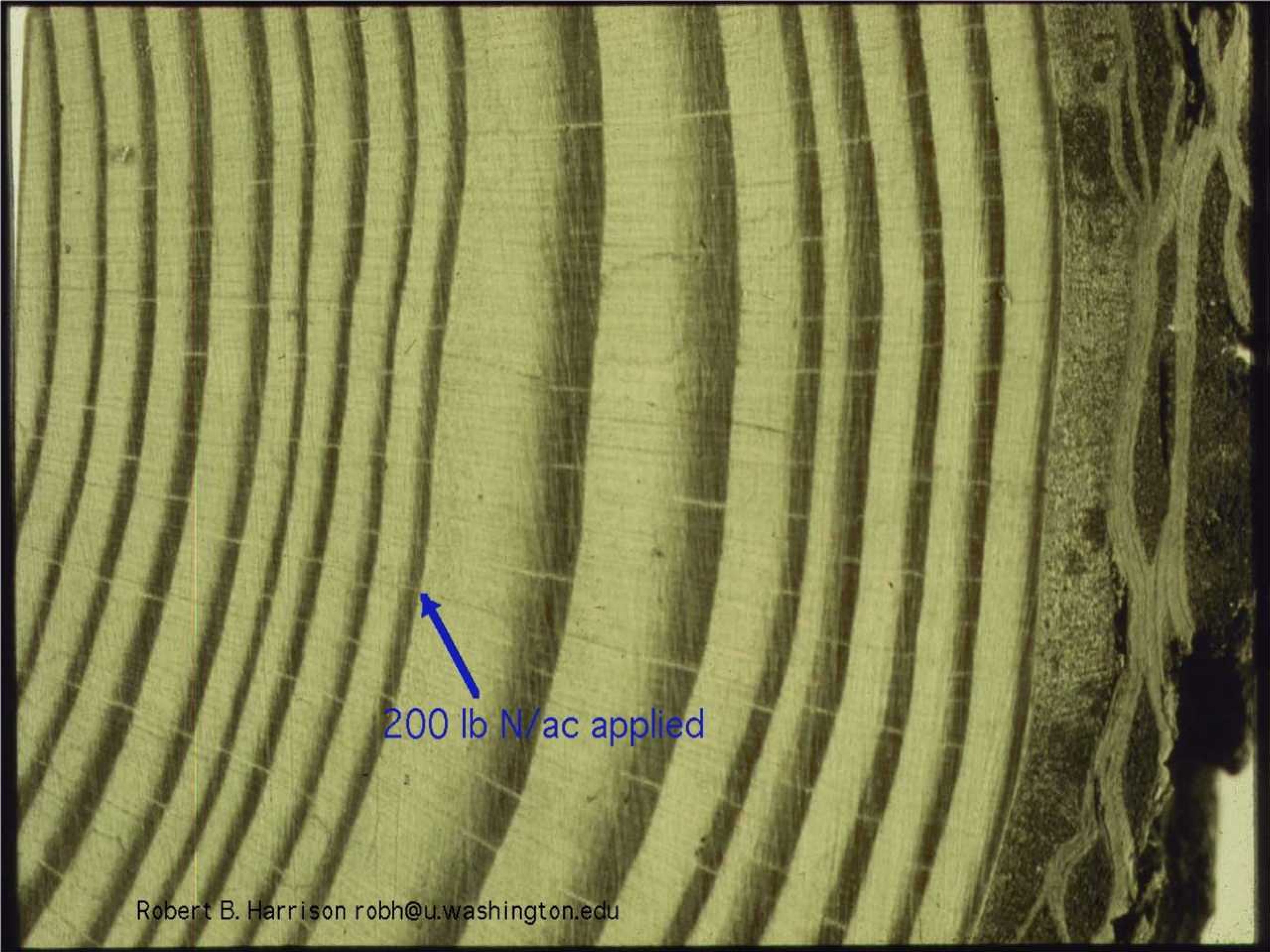
Shelton-Carson Lake study. Each treatment 2 reps



Shelton-Matlock study. Each treatment 2 reps




Percent volume response
N rate (lb N/acre)
N200-P88-S168+
N200-P88-S154
N100
N200
N300
N52-P12-K220
0
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350


200 lb N/ac applied
Robert B. Harrison robh@u.washington.edu

Conclusions of early studies

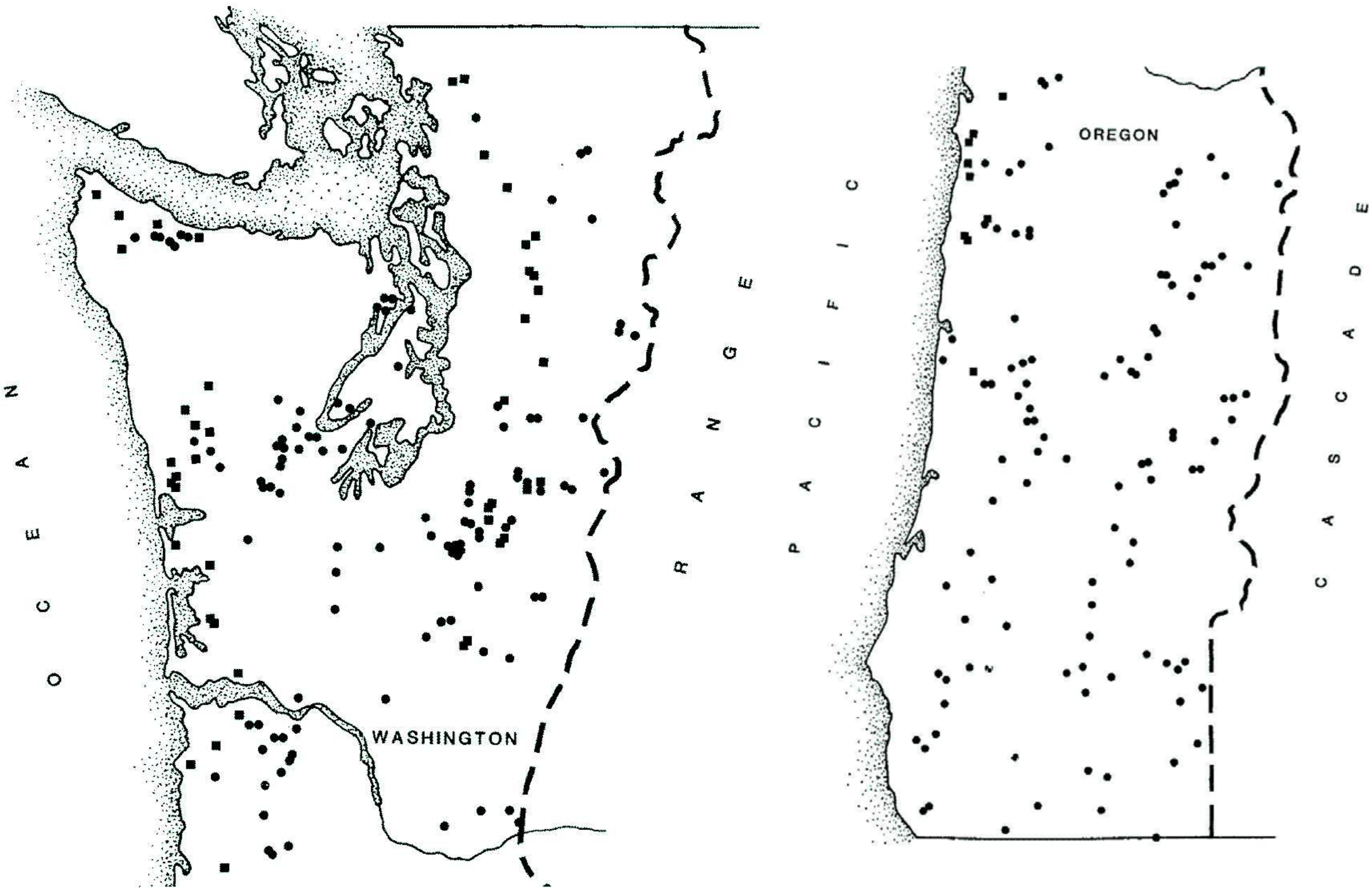
1) “Nitrogen application evoked a growth response throughout a range of growing conditions. Magnitude of response is related to amount of nitrogen applied and response is still evident in 1975 from a 1962 application”.

2) “Apparent response to the application of other elements is quite variable and no consistent picture emerges. There is no evidence of an economic response to the other elements”.

RFNRP
1969-pres.

Installations of the PNW Stand Management Cooperative

Stand Management Cooperative
SILVICULTURE
ton
Box 352100
Seattle Washington 98195-2100
206-543-5355 phone
206-685-3091 fax

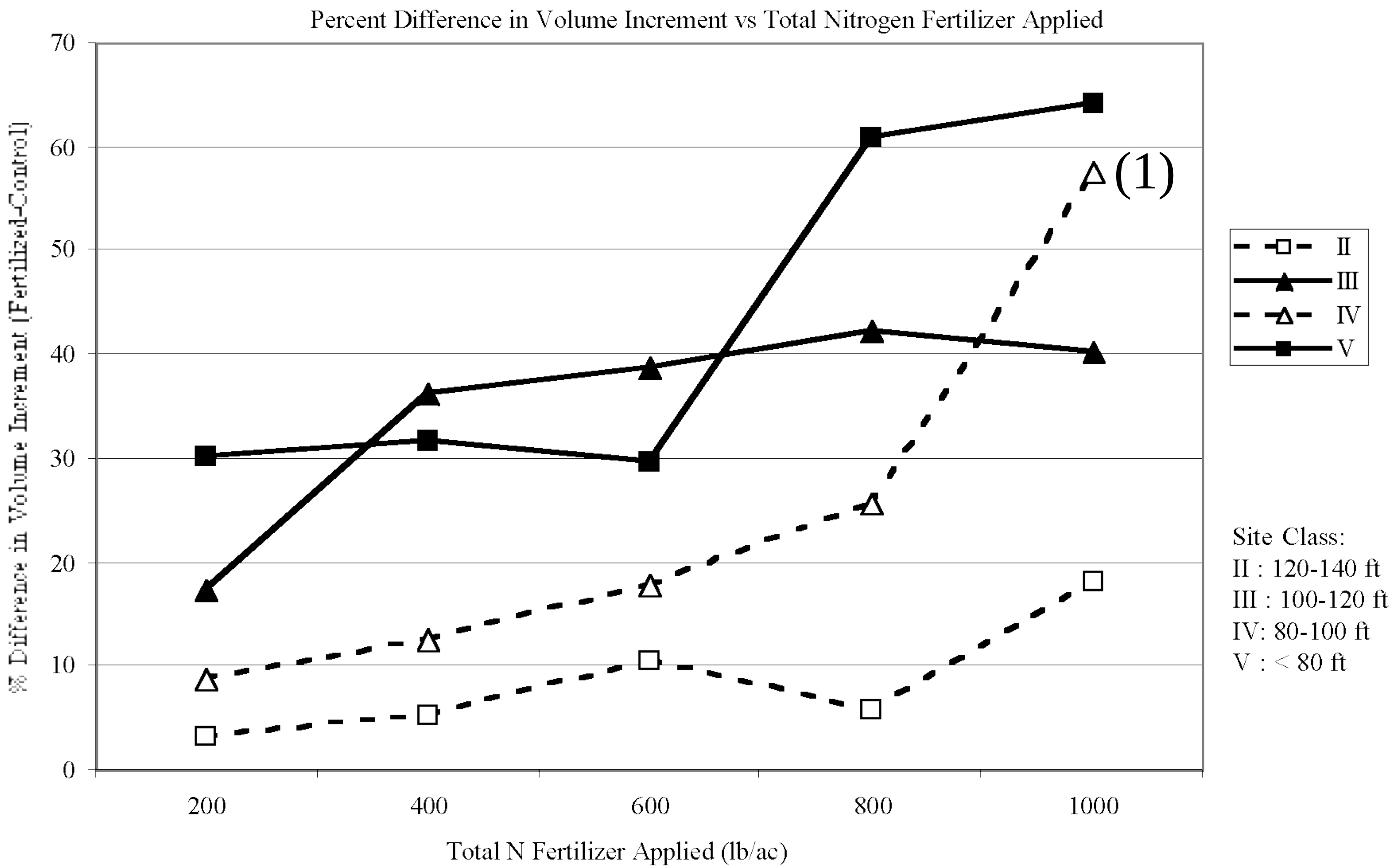


RFNRP Installations

- **Phase I Unthinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1969/70
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase II Thinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1971/72
  - up to 4 fertilization treatments
  - 20 years growth remeasurements

RFNRP Installations

- **Phase III Young, Thinned Plantations**
  - Douglas-fir & western hemlock
  - established in 1975
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase IV PCT Plantations**
  - Douglas-fir & western hemlock
  - established in 1980
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase V Single Tree Screening Trials**
  - young noble fir & pacific silver fir
  - established in 1986/88
  - one fertilizer application
  - 6 years growth remeasurements



Overall results of SMC studies Response vs. N rate. Sidell thesis.

SMC "Carryover" Study

- long-term impacts of previous N fertilization on future stand growth
- N applications made up to 20 years previously

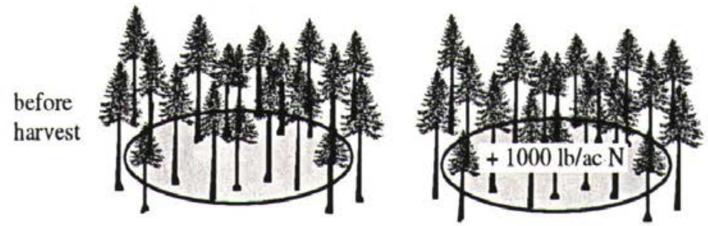


Figure 1. Douglas-fir stands at beginning of the study.

Figure 2. Stands after harvesting and slash distribution.

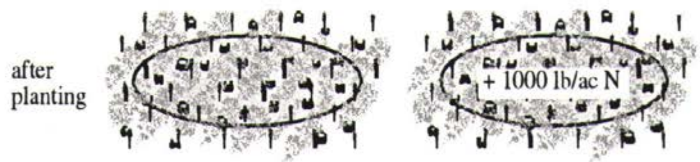


Figure 3. Stands following planting with identical stock.

Figure 4. Growth of young stands, with possible differentiation.

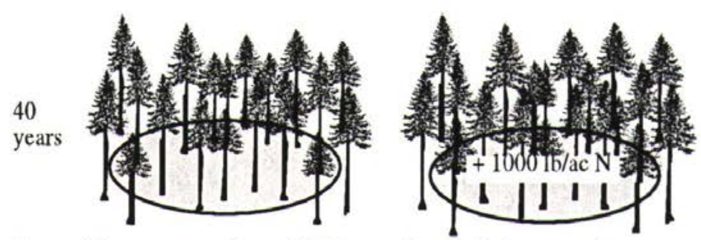
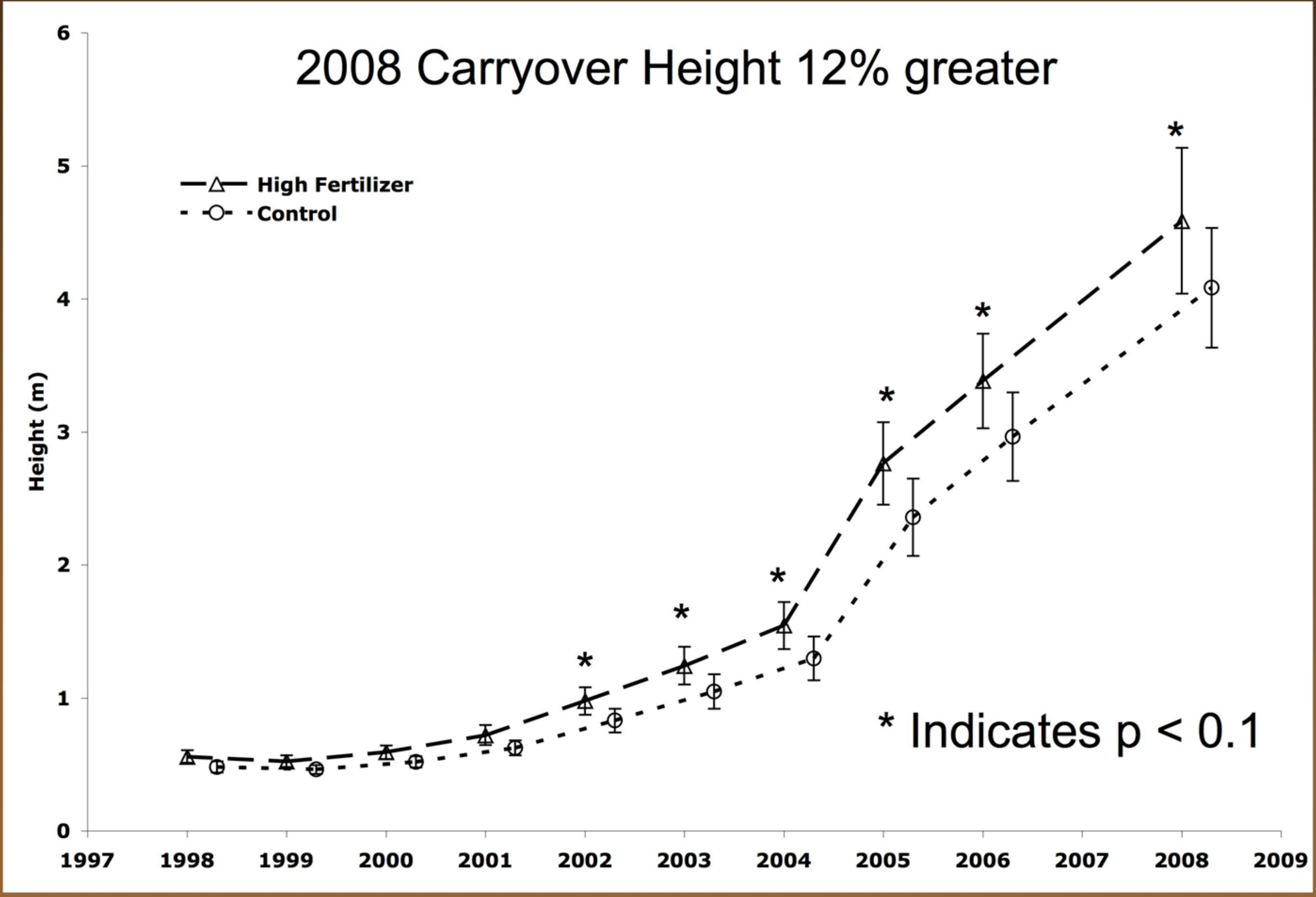


Figure 5. After 40 years. Possibility of studying subsequent rotations.

Mean Height



2008 Carryover Height 12% greater
High Fertilizer
Control
Height (m)
6
5
4
3
2
1
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
* Indicates p < 0.1

SMC carryover study results 5-7 years of growth

Install.	Name	App. Rate	yr since planting	Vol-ind Control	Vol-ind +N	% Vol-ind Difference
		- lbN/ac-	— y —	—— index only	——	— % —
17	Little Ohop Creek	1000	5	5.12	7.35	16
53	Camp Grisdale	1000	5	2.12	2.61	10
53	Camp Grisdale	400	5	2.12	2.15	16
134	Pack Forest	1000	7	3.36	6.24	22
156	Coyle	1000	5	2.79	5.05	17
167	Hanks Lake	1000	6	1.58	3.40	11
167	Hanks Lake	400	6	1.58	4.03	25
168	Simpson Log Yard	1000	6	1.75	2.69	8
168	Simpson Log Yard	800	6	1.75	2.37	11
168	Simpson Log Yard	200	6	1.75	1.32	-1
177	Pack Forest Lookout	1000	6	2.70	2.50	13
177	Pack Forest Lookout	800	6	2.70	3.98	28
					Average	**15**
					prob =	**0.0017**

Volume index is not an actual volume, as it is calculated as diameter squared times the height…thus it is useful for comparison only.

SMC (1991+)

No multi-element additions. SMC Type II, III and IV no fertilizer work at all

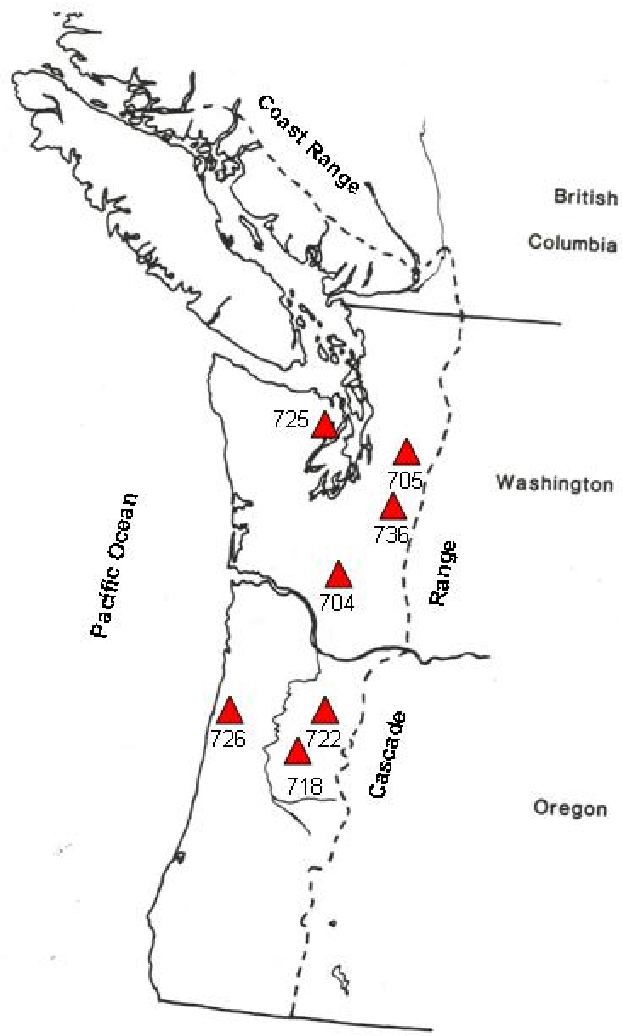
SMC Type I Installations
-plantations with initial stocking 300-680 spa
-Respace (PCT) before onset of competition

-7 core treatments (basic 7)
ISPA, ISPA/2, ISPA/4,
ISPA and ISPA/2 min thin
ISPA repeated thin
ISPA heavy thin

2-8 plots for other work, including fertilization

Eric Sucre did his M.S. on 7 fertilized sites

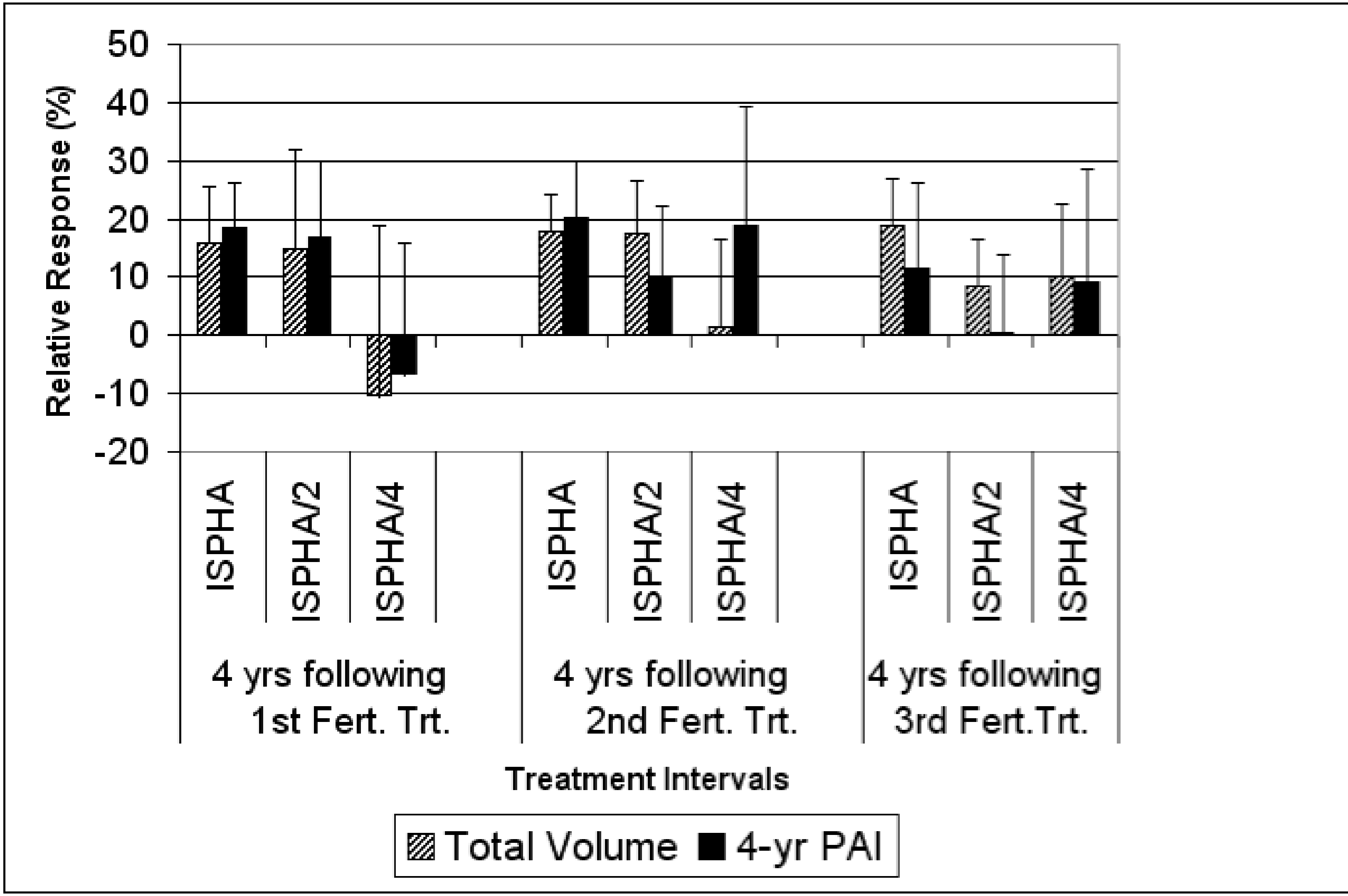
Location of SMC Type 1 Fertilized Research Installations



Soil & Site Properties Examined

- Climatic data
- Elevation
- % Slope
- Relative Density (RD)
- Quadratic Mean Diameter (QMD)
- Site Index (SI)
- bulk density (Db)
- pH
- C:N ratio
- cation exchange capacity (CEC)*
- Inorganic nitrogen (NO_3^- and NH_4^+)*

*Mineral Soil only



Total volume and 4-year PAI relative response for each treatment regime at the respected treatment intervals (224 kg ha^{-1} of N as urea every 4 years). Standard errors are shown.

Dependent Variable	N	Equation	Adj-R^2
<u>All DMR's</u>			
Total Volume	42	$-634.1 + 22.396RD + 7.00QMD$	0.592
		$61.8952pH_{30\text{-}50cm} + 0.00108C_{0\text{-}15cm} - 0.027PPT$	
4-yr PAI	42	$-13.59 + 0.08135NW_{FF}$	0.091
<u>ISPHA</u>			
Total Volume	14	$-398.96 + 54.43RD + 4.852CN_{FF} - 4.98CN_{0\text{-}15cm}$	0.722
	14	$164.541 - 7.566CN_{0\text{-}15cm}$	0.456
4-yr PAI	14	$-57.066 + 3.6397NH_{4(15\text{-}30cm)}$	0.622†
	14	$-37.339 + 2.824NH_{4(30\text{-}50cm)}$	0.368
<u>ISPHA/2</u>			
Total Volume	14	$-238.22 + 41.24RD$	0.712†
4-yr PAI	14	$-144.39 + 34.397pH_{15\text{-}30cm} - 9.973\%C_{30\text{-}50cm}$	0.666
<u>ISPHA/4</u>			
Total Volume	14	$-197.94 + 50.897RD + 12.29\%C_{0\text{-}15cm}$	0.882
		$- 3.68NH_{4(30\text{-}50cm)} - 0.041ELEV$	
4-yr PAI	14	$56.801RD - 5.56QMD + 77.51\%N_{15\text{-}30cm} + 0.002CW_{FF}$	0.881

† Strongest single indepent variables shown in Fig. 3

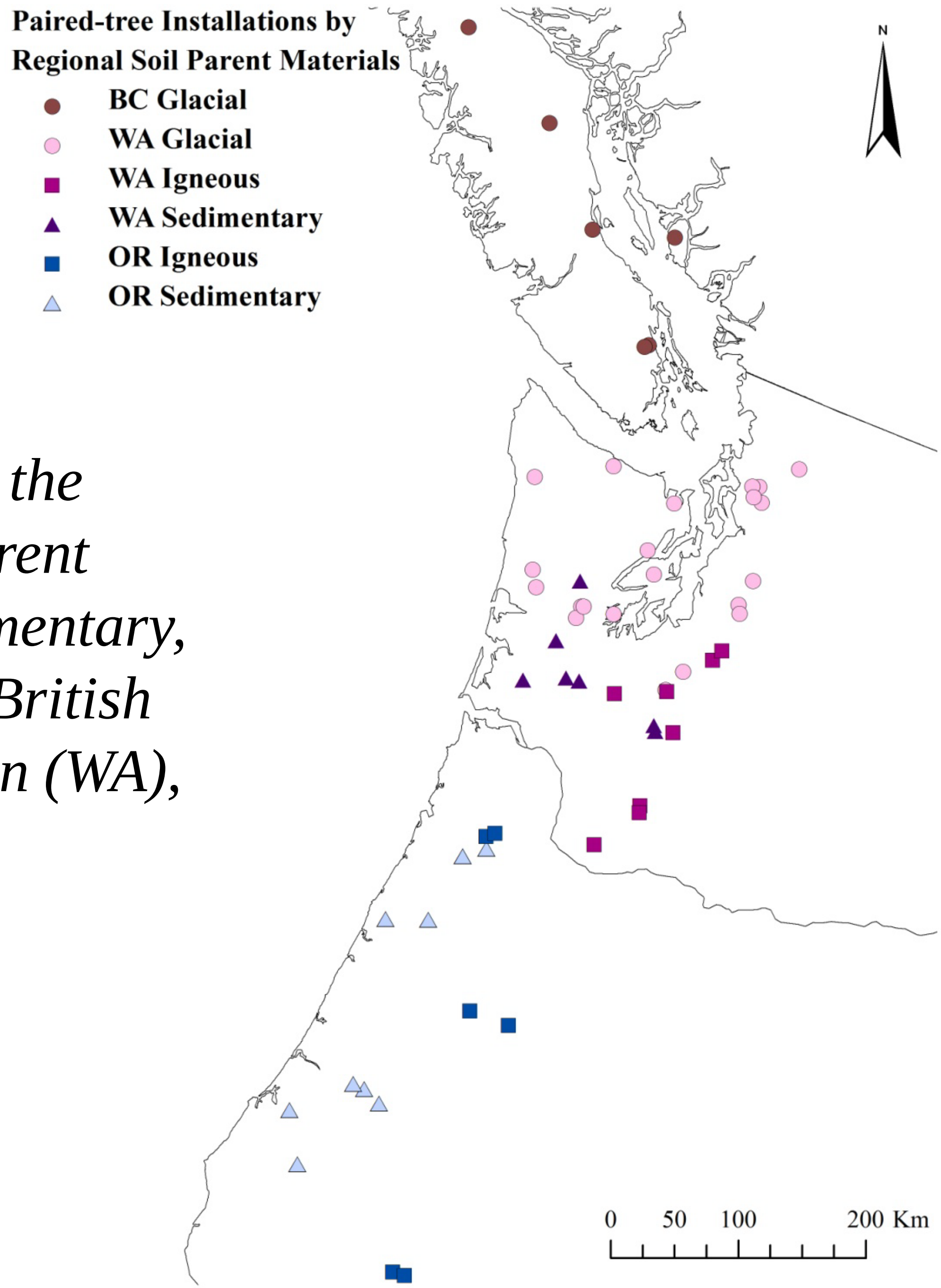
Multiple regression equations for the relationships between the unstandardized residuals of total volume (m^3 ha^{-1}) and 4-year PAI (m^3 ha^{-1} yr^{-1}) response to 224 kg N ha^{-1} as urea (dependent variables) and various soil, site and stand variables (independent variables).

Results of SMC studies

too few sites (7) for broad generalizations

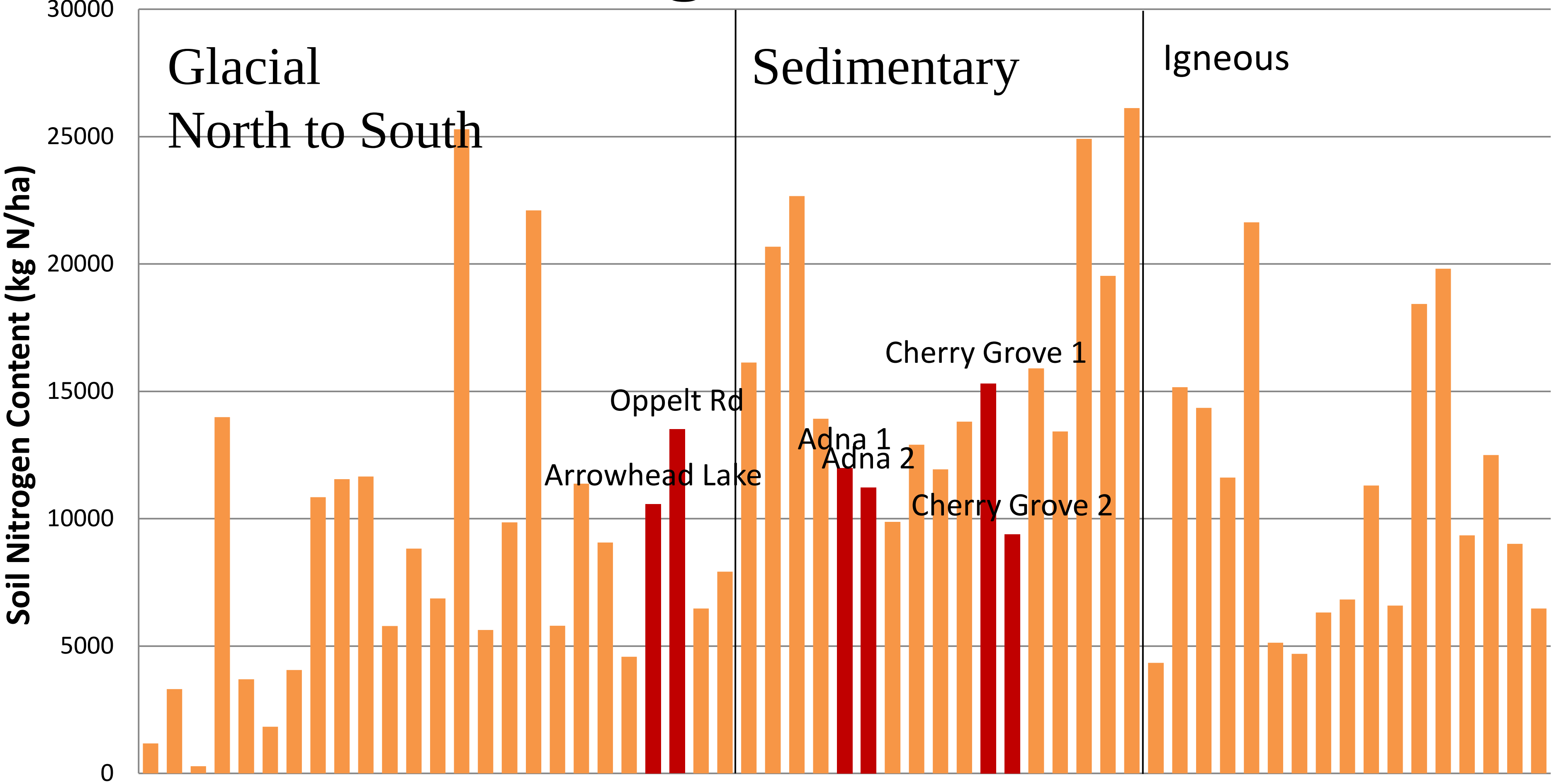
1) Response to N is site and stand controlled. Indicates need to couple fertilization with other silvicultural treatments, particularly stocking, and use RD or other stand properties to drive time of fertilization.

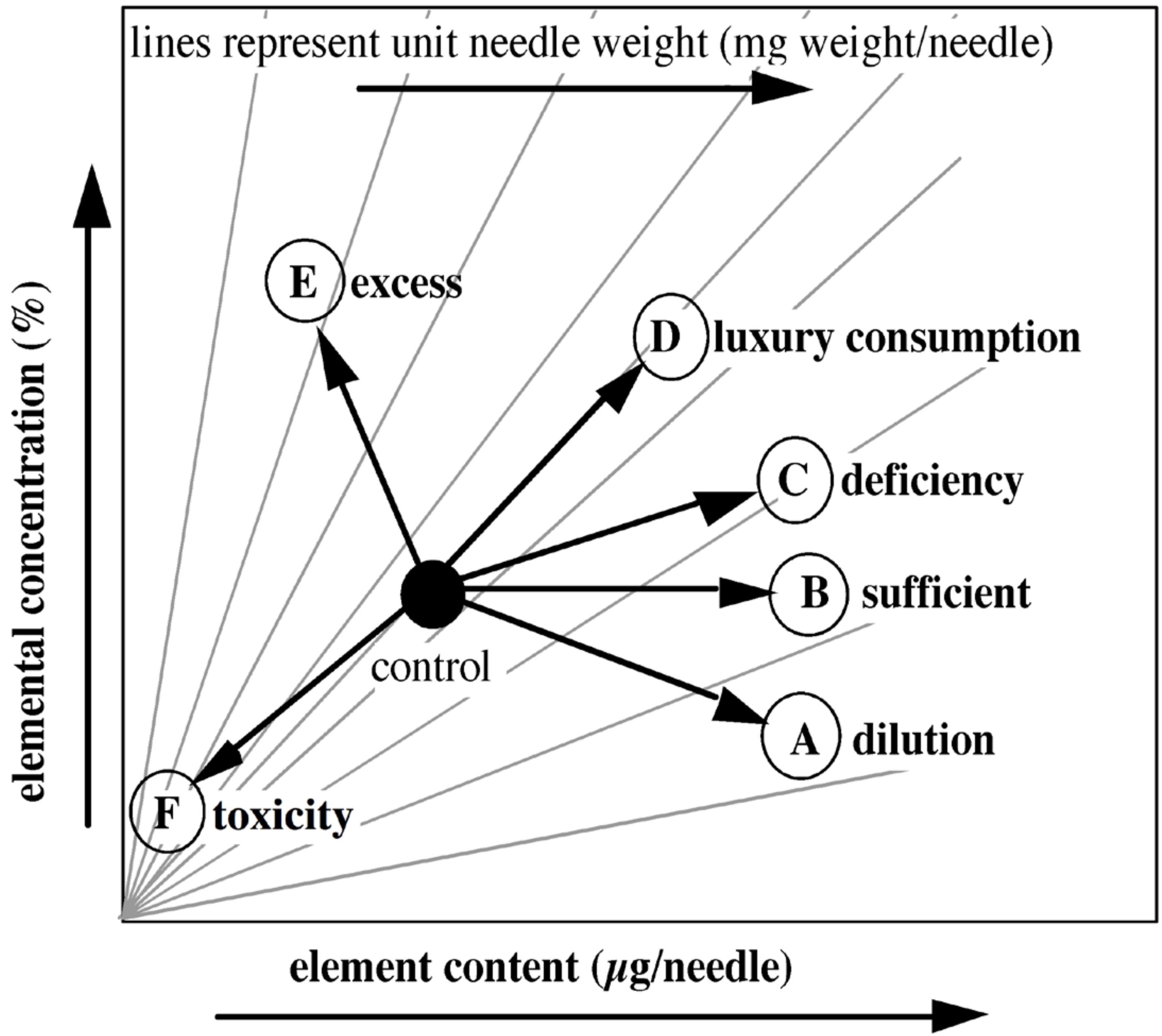
SMC Type V Installations
- paired-tree fertilization studies
- good stocking and 15-20 years old
- designed to determine responders from non-responders, but not necessarily yield



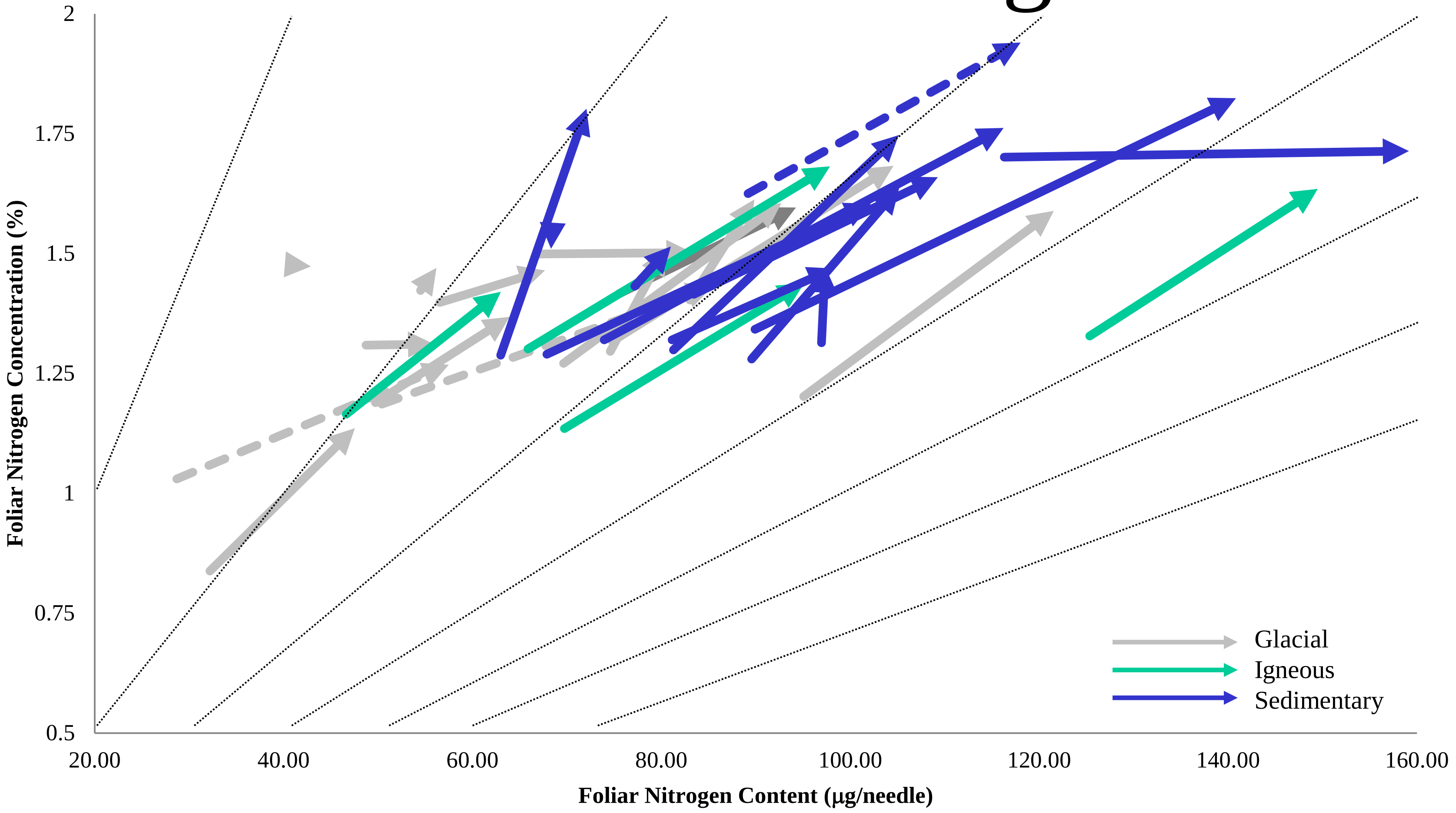
Paired-tree installations in the Pacific Northwest. Soil parent materials are glacial, sedimentary, and igneous. Regions are British Columbia (BC), Washington (WA), and Oregon (OR).

Soil Nitrogen to 1 Meter




lines represent unit needle weight (mg weight/needle)
E excess
D luxury consumption
C deficiency
B sufficient
A dilution
F toxicity
control
elemental concentration (%)
element content (μg/needle)

Foliar N and weight



Center for Advanced Forestry
Systems 2011 Meeting

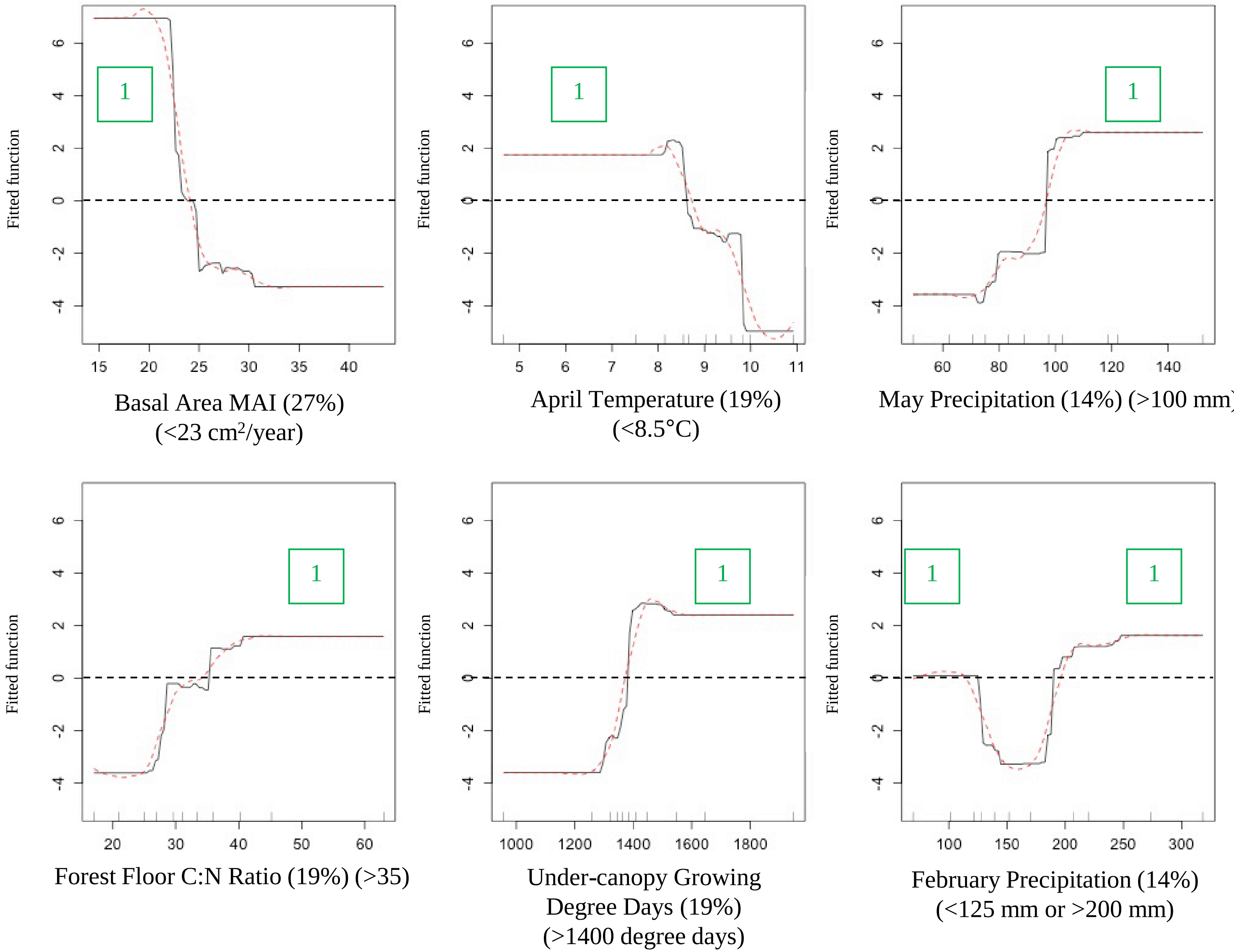


Figure 5. Boosted regression tree partial dependence plot model and predictor criteria for fertilizer volume response.

Table 1. Fertilizer volume response according to three levels of model criteria: Low (<33%), Medium (33-66%), and High (>66%).

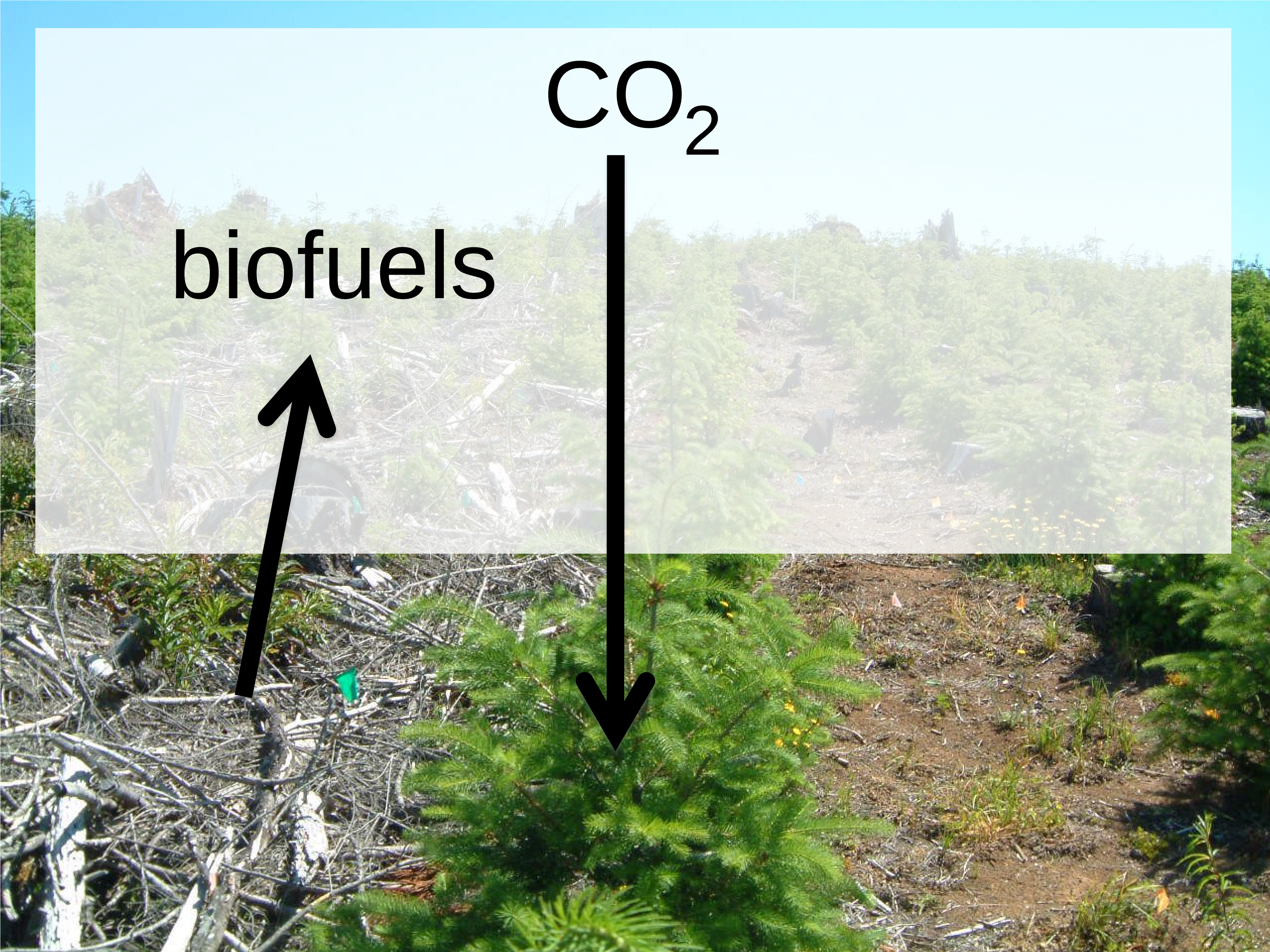
Model Criteria	Mean Fertilizer Response (%)	Standard Error	Sig.	p-value
Low	3.5	1.4	a	
Medium	10.7	2.0	b	<0.001
High	23.4	3.6	c	

First of Its Kind: WSU Led Bio-Jet Fuel Project Officially Gets Off the Ground

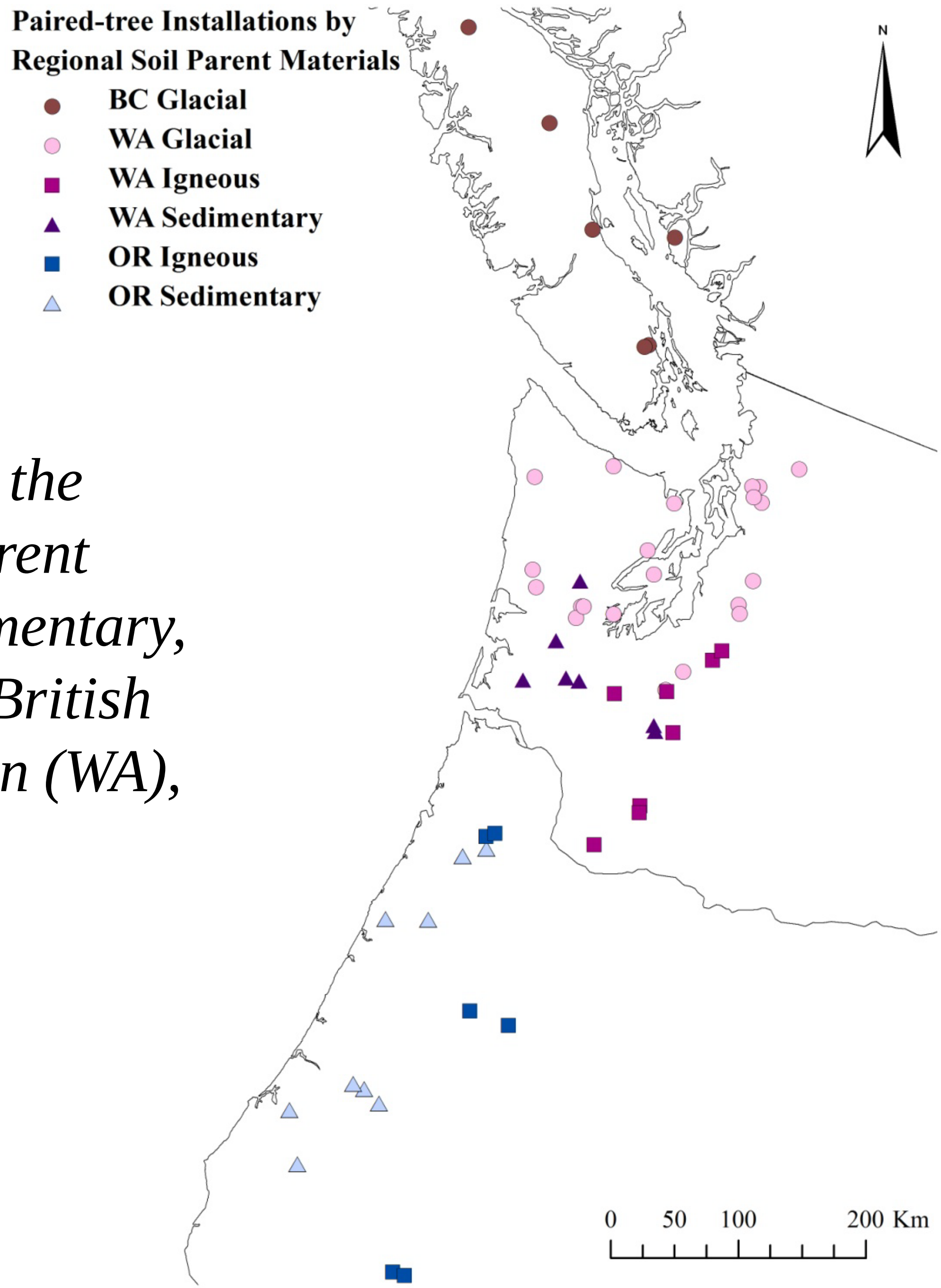
US$40 million to Univ. Washington
US$40 million to Washington State U

PULLMAN, Wash. -- A major Washington State University effort to develop aviation bio-fuel is underway with the announcement of a strategic initiative called the "Sustainable Aviation Fuels Northwest" project; the first of its kind in the U.S. In partnership with Alaska Airlines, Boeing, the Port of Seattle, The Port of Portland, and Spokane International Airport, the project will look at biomass options within a four-state region as possible sources for creating renewable jet fuel.

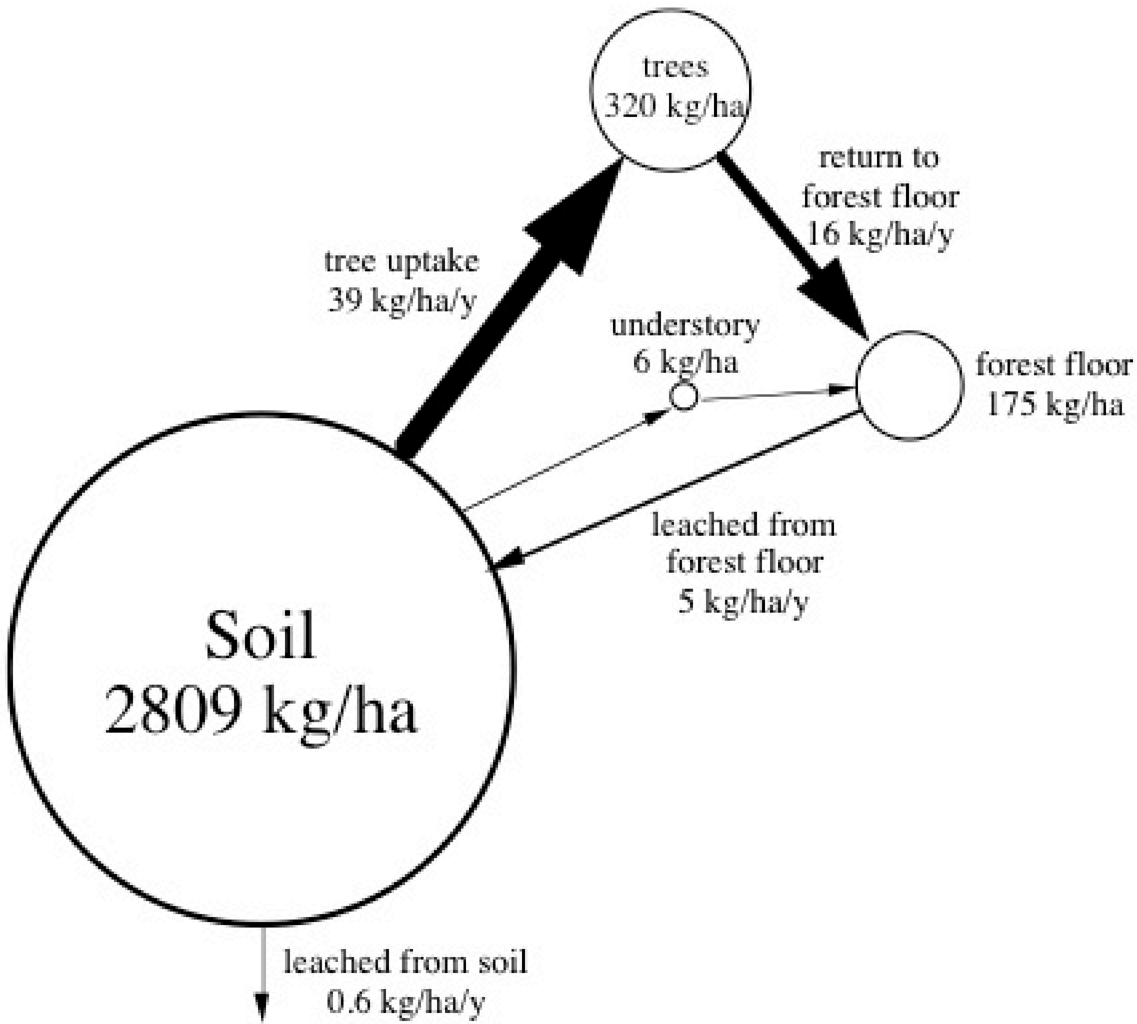
"This really is an exciting development from both the economic impact to the Northwest, but also to the advancement of clean fuel technologies world-wide," said John Gardner, vice president of Economic Development and Global Engagement at WSU.


CO_2
biofuels

Paired-tree installations in the Pacific Northwest. Soil parent materials are glacial, sedimentary, and igneous. Regions are British Columbia (BC), Washington (WA), and Oregon (OR).



N Cycle of 60-y-old Douglas Fir Cedar River Watershed



Analysis of Sustainability

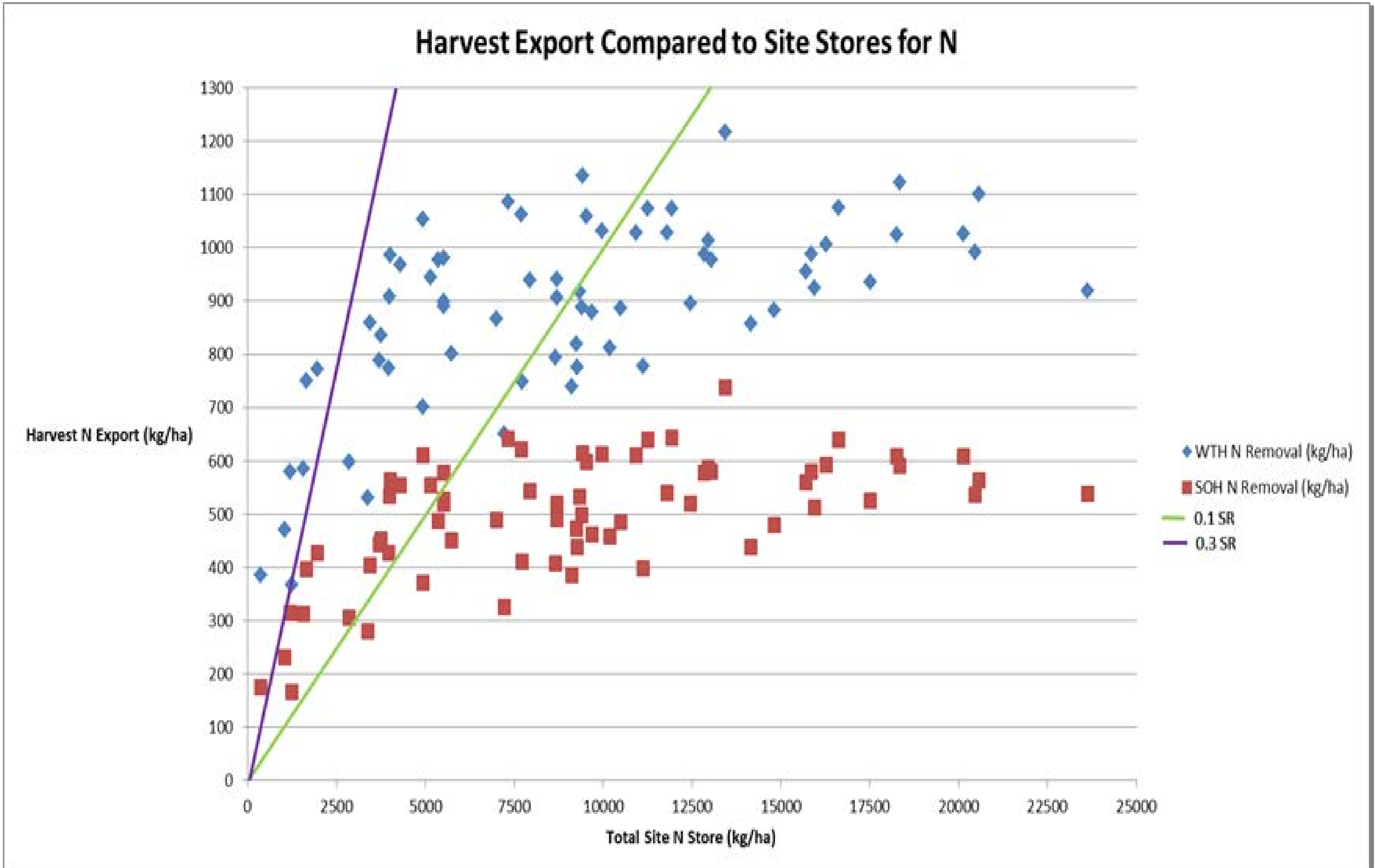
- Evans (1999) Stability Ratio
  - The ratio of the quantity of a particular nutrient removed at harvest compared to site nutrient stores of that nutrient
    - <0.1=low risk
    - >0.3=depletion and loss of productivity likely in the future
    - >0.5=immediate depletion and loss of productivity

Example Analysis: Fall River LTSP Nutrient Risk Ratings for N loss from Harvest

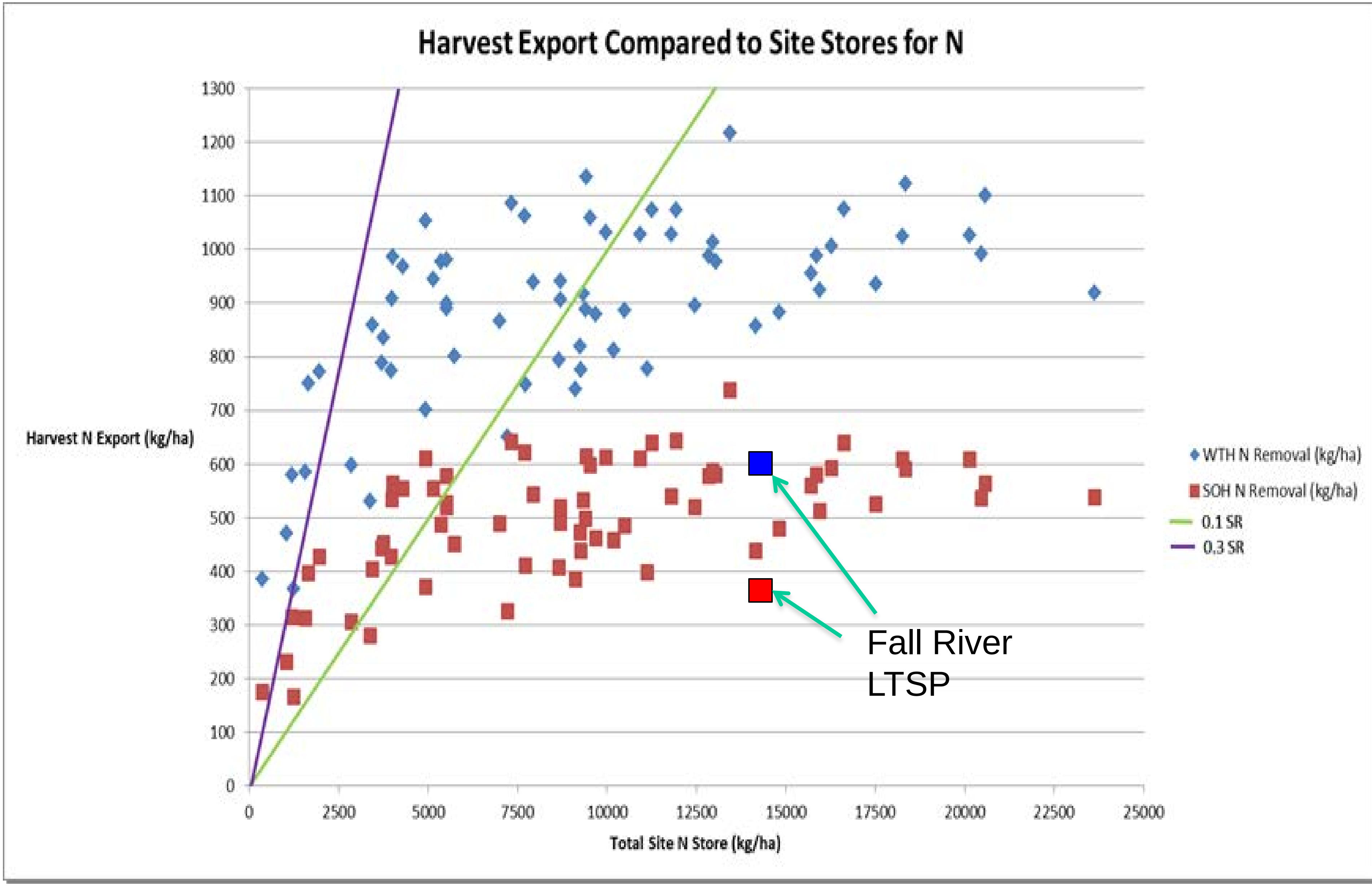
Ecosystem Part	Biomass	Carbon	Nitrogen	N Risk Rating	Harvest Scenario
	– Mg/ha –	– Mg/ha –	– kg/ha –		
Bole	341	167	359	0.02	bole-only harvest
Branches	42	21	84		
Foliage	9.5	4.9	162		
Tree AG	393	193	604	0.04	total-tree harvest
CWD	22	11	75		
Stumps/Snags	29	17	26	0.05	add stumps/snags
Understory	0.2	0.09	5		
Forest Floor	71	27	453	0.08	add forest floor
Roots	86	41	215	0.09	add roots
Soil (0-80cm)	459	239	13143		
Ecosystem Total	**1147**	**582**	**14672**		

	Removal vs. N Risk Rating
0.10	low chance of decline
0.30	serious chance of decline
0.50	imminent decline

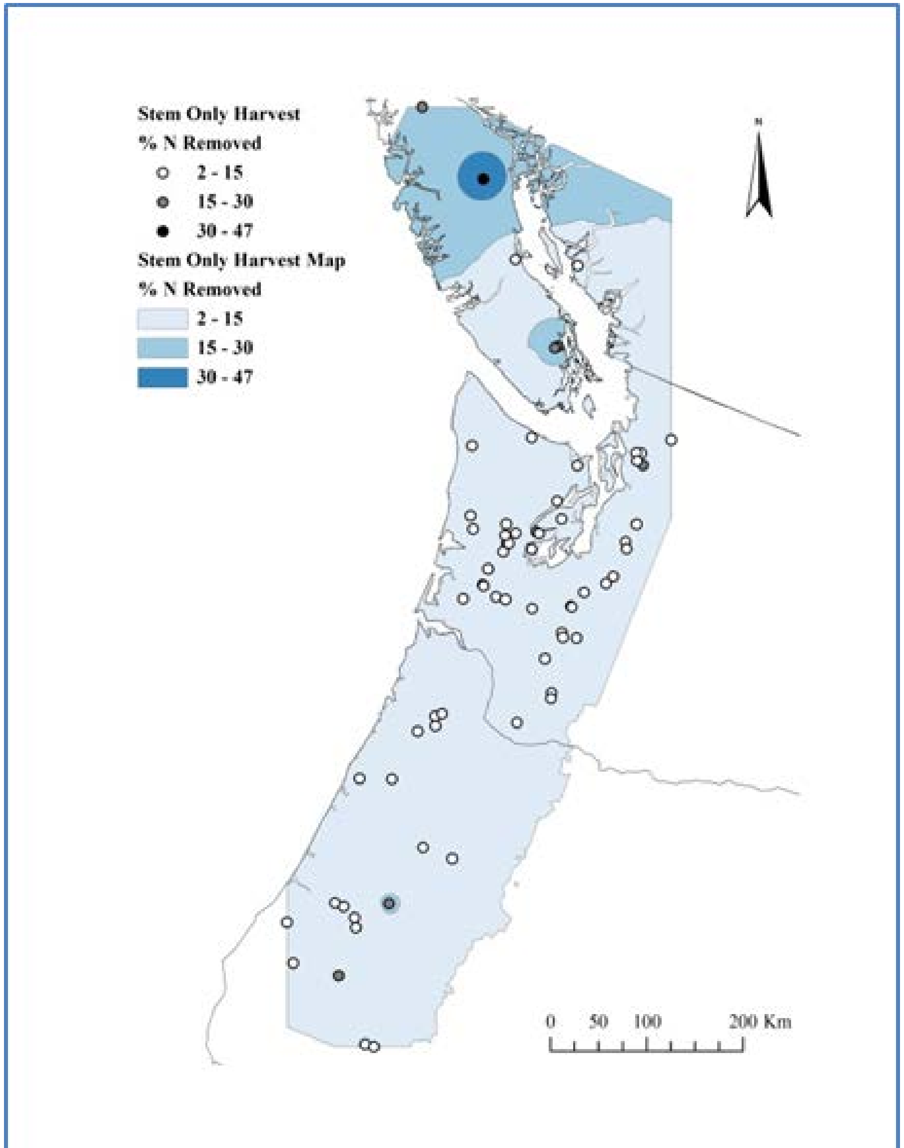
Source for risk rating: Evans, J. 1999 Sustainability of plantation forestry: impact of species change and successive rotations of pine in the Usutu Forest, Swaziland. *Southern Africa Forestry Journal 184: 63–70.*

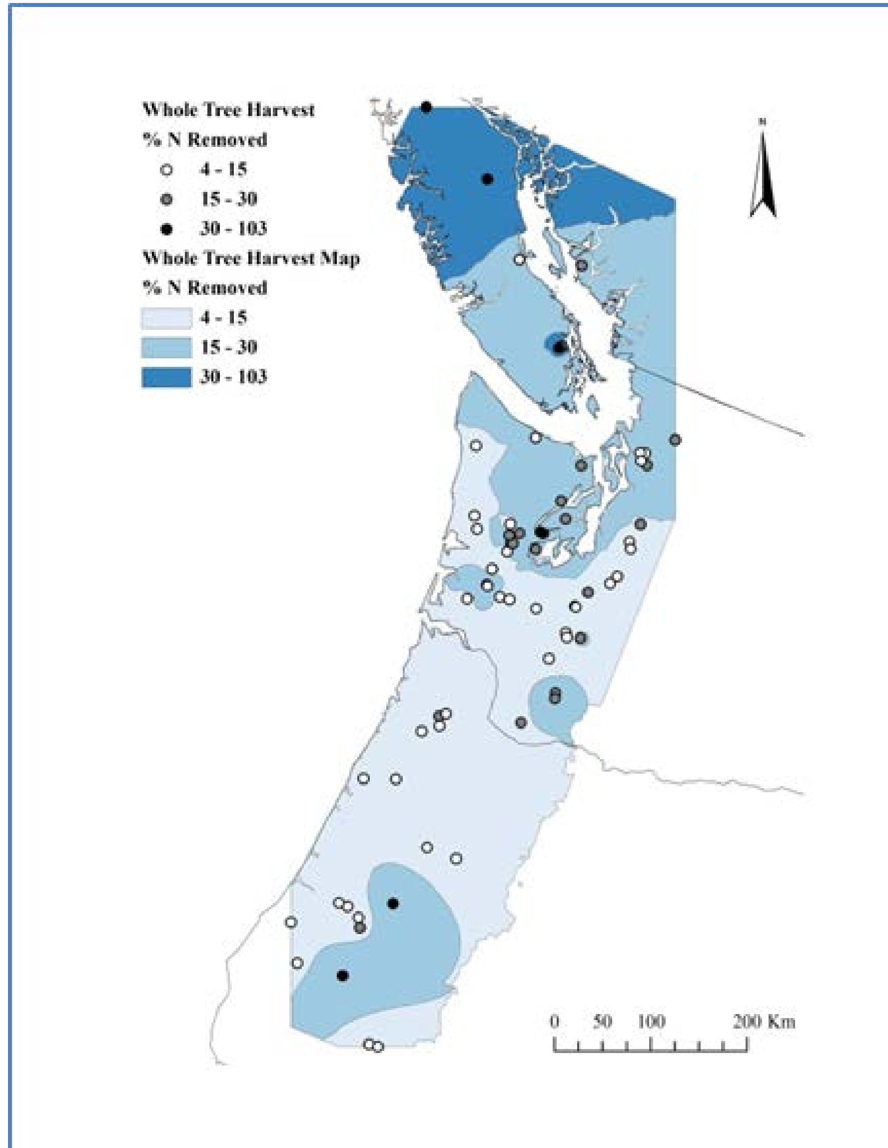


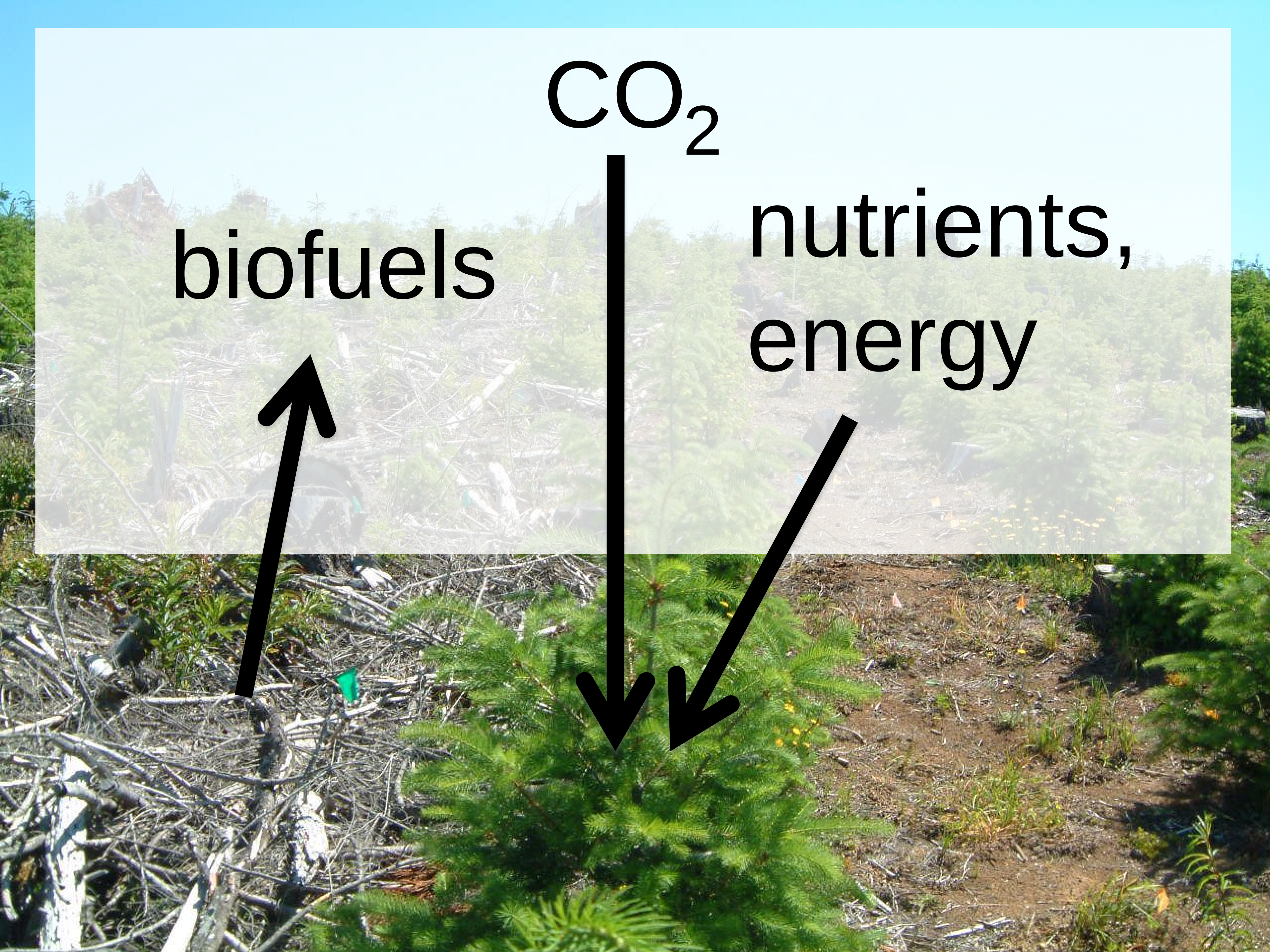
Harvest Export Compared to Site Stores for N
Harvest N Export (kg/ha)
Total Site N Store (kg/ha)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
WTH N Removal (kg/ha)
SOH N Removal (kg/ha)
0.1 SR
0.3 SR


Harvest Export Compared to Site Stores for N
Harvest N Export (kg/ha)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
Total Site N Store (kg/ha)
WTH N Removal (kg/ha)
SOH N Removal (kg/ha)
0.1 SR
0.3 SR
Fall River
LTSP

Results Regionalized



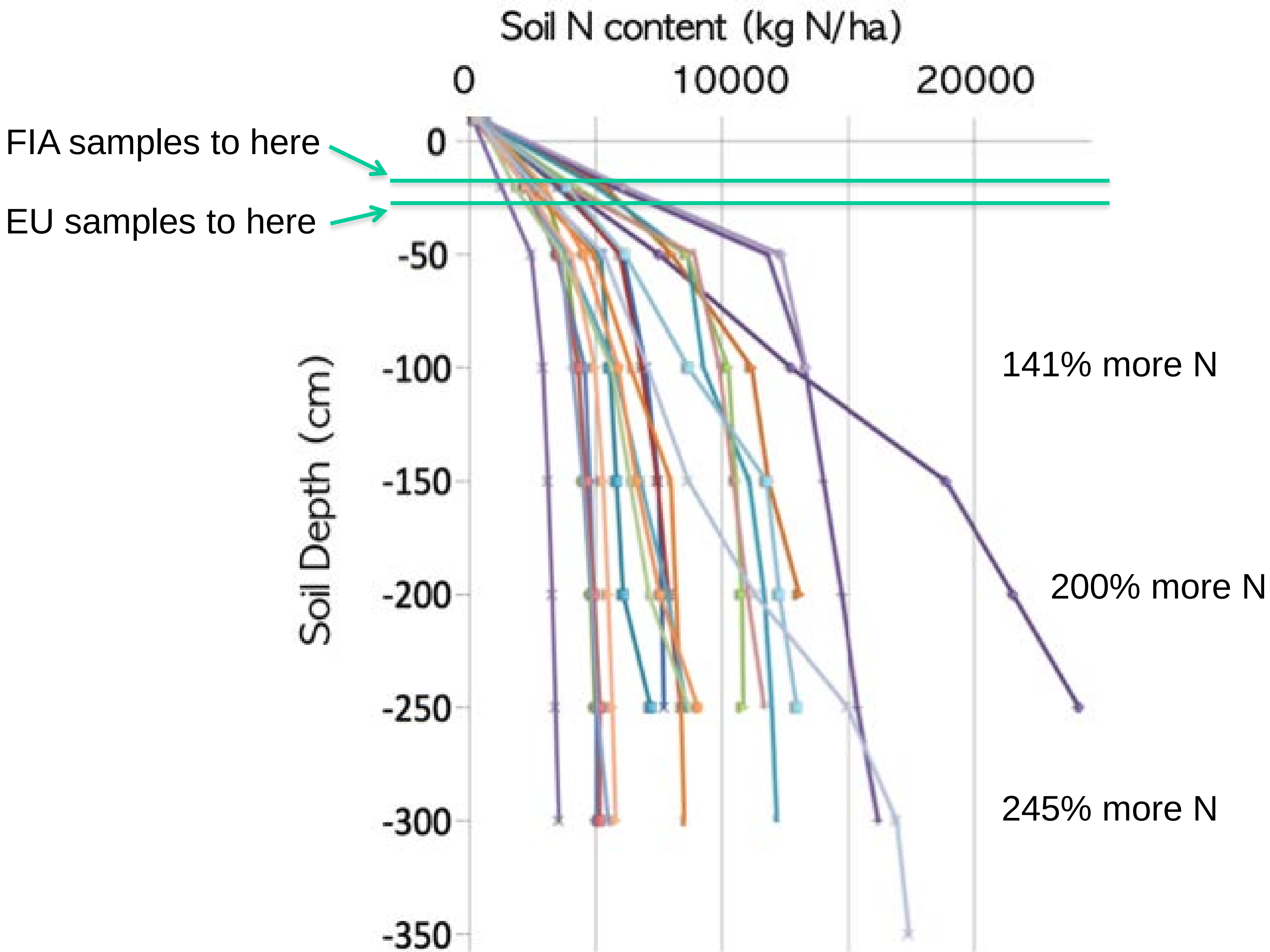




CO_2
biofuels
nutrients,
energy

Next Steps for Sustainability Evaluation

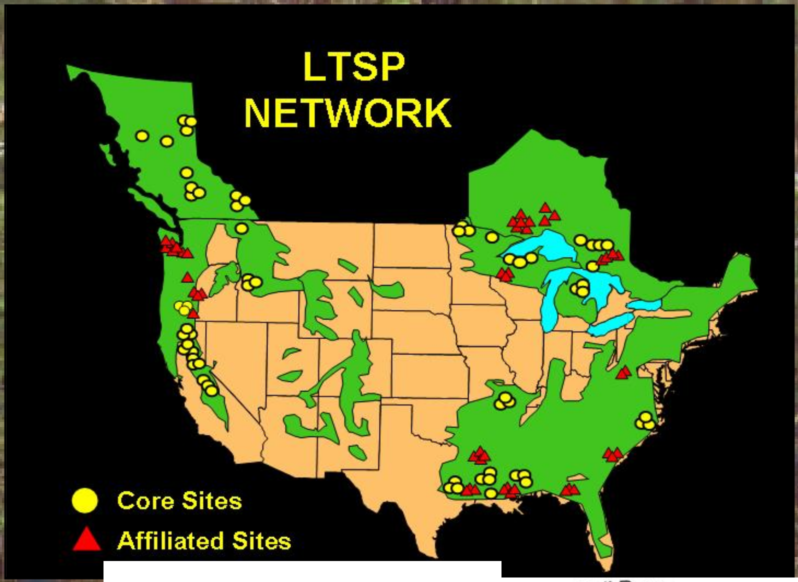
- what about other nutrients?
- can site or easy-to-measure factors predict N depletion with additional biomass removal?
- what is the true ecosystem pool available to replace additional removals?

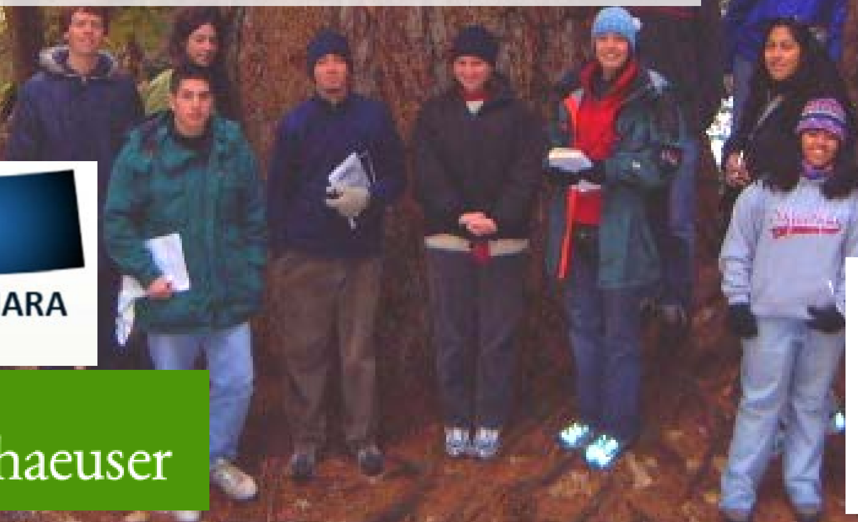



Soil N content (kg N/ha)
0
10000
20000
FIA samples to here
EU samples to here
Soil Depth (cm)
0
-50
-100
-150
-200
-250
-300
-350
141% more N
200% more N
245% more N

Challenges:

Thanks to PNW Stand Management Cooperative (26 members), Northwest Advanced Renewables Alliance (NARA) National Council for Air and Stream Improvement (NCASI), USFS/DOE Agenda 2020, NSF Center for Advanced Forest Systems, Univ. Washington Kreuter/Gessel Scholarships. These are affiliate sites of the USFS long-term soil prod. network.





USDA NIFA

Long-Term Soil Productivity Study
LTSP
Est. 1989

NARA

Weyerhaeuser

LTSP
Sine solo nihil

Stand Management Cooperative
SILVICULTURE ▪ NUTRITION
WOOD QUALITY ▪ MODELING

ncasi
National Council for Air and Stream Improvement, Inc.

CAFS
Center for Advanced Forestry Systems
NSF